GEOTECHNICAL PROJECT DEVELOPMENT MANUAL

ADOT Bridge Group
Geotechnical Services

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1 CHAPTER 1 – INTRODUCTION

1.1 GENERAL

This Geotechnical Project Development Manual (GPDM) was developed by the Geotechnical Services of the Arizona Department of Transportation (ADOT) Bridge Group for the purpose of establishing standard procedures and guidelines for preparation of geotechnical design reports. The GPDM covers general aspects of all phases of the geotechnical program from initial planning; site and subsurface investigations, analysis and design, reporting to support, and monitoring during construction of transportation facilities. It is intended that the procedures presented herein will establish a reasonable and uniform set of guidelines and procedures while maintaining sufficient flexibility to permit the application of engineering judgment to aid in developing practical low-risk solutions to geotechnical conditions and problems.

It is intended that topics covered herein will provide the staff of ADOT Geotechnical Services and parties external to ADOT Geotechnical Services a basic understanding of the general geotechnical requirements to accomplish tasks related to ADOT assets. External parties may include ADOT Department Sections, ADOT Districts, consultants, contractors, and the public.

The GPDM also serves as a portal to technical information and resources required for conducting geotechnical services for ADOT. It presents standards for tasks and activities to be delivered, but is not intended to be a technical guidance or a quality manual on how-to execute the tasks. For assistance with how-to execute and perform the essential duties of the geotechnical engineer, the reader is directed to more widely published technical guidance reference documents. They include information provided in the U.S. Department of Transportation, Federal Highway Administration (FHWA) Geotechnical Technical Guidance Manual (2007).

The GPDM is organized into chapters which presents various logical subjects of importance in the accomplishment of work for ADOT Geotechnical Services.

It is recognized that guidelines and procedures may be subject to differing interpretations and that the GPDM would be too lengthy for practical use if all areas were covered definitively. It is also understood that occasions will arise, which may warrant the consideration of exceptions or variations to items described in the GPDM. Any properly authorized exceptions or variances to the GPDM are to be considered as "one time only" changes, unless otherwise directed.

The intent of the GPDM is to provide geotechnical project and development guidance rather than serve as a design portal. The Engineer is expected to direct or conduct the Geotechnical Investigation and prepare the Geotechnical Report according to acceptable practice and professional standards of that of a State of Arizona licensed Professional Engineer or Registered Geologist.

Geotechnical design of all ADOT projects are subject to discussion and concurrence by ADOT Geotechnical Services during the early stages of the project and adjusted accordingly as necessary to adequately address the geotechnical conditions as the project progresses.

The GPDM replaces and supersedes the geotechnical portions of the 1989 ADOT Preliminary Engineering and Design Manual.

1.2 MANUAL UPDATES

This GPDM will be updated as required to include new information and to provide guidance on best practice approach for the geotechnical practice at ADOT. Users should ensure they are utilizing the proper version of the GPDM. Updates to the GPDM will be available electronically through the ADOT website.

1.3 REFERENCE MATERIALS

Federal Highway Administration (FHWA) reference manuals for work on Federal Lands projects include the upcoming FHWA Geotechnical Fundamentals for Transportation Projects manual (estimated release in Spring 2021) which is replacing the FHWA Soils and Foundation Reference Manual Volumes I and II (FHWA NHI 06-088 and 06-089). Another source is the U.S. Department of Transportation FHWA Office of Federal Lands Highway - Project Development and Design Manual. These are good tools to be considered as primary resources for a wide range of geotechnical engineering topics. Direct application of recommendations included in the manuals that may differ from those provided in this GPDM, would be discussed and approved as warranted on a case by case basis by ADOT Geotechnical Services.

1.4 GEOTECHNICAL DISCIPLINE

The state-of-the-practice of the geotechnical field involves engineering judgment and experience in providing the most efficient and economical investigations and designs. While this GPDM provides standards and direction to specific guidance, it is not intended to limit the individual Geotechnical Professional from exercising their professional judgment and experience. Dealing with the variability of ADOT projects, geology, terrains, climates, and partner agency constraints requires flexibility and resourcefulness. Geotechnical work is to be conducted in accordance with accepted geotechnical standards-of-care by engineers or engineering geologists who possess adequate geotechnical training and experience.

Geotechnical explorations are often constrained by limitations of time, staffing resources, equipment, clearances (e.g., environmental, right-of-way), contracts, access, or funds. It is important that the investigative program be designed and conducted in a manner that will provide data in a timely and cost-effective manner, and at a level that is sufficient to manage risks and meet the needs of the design team.

Project schedules are influenced by the National Environmental Policy Act (NEPA) requirements, and the availability of funding. Once these aspects of the project are in place, the design team is typically anxious to obtain geotechnical data. When scheduling geotechnical explorations, consideration should be given to time requirements for review and approval of work plans, boring and access plans, right-of-way approval, environmental clearance, utility clearance, funding, contracts, etc. These potential time constraints should be incorporated into the project schedule in the planning stage of the project.

1.5 RISK MANAGEMENT

Risk is inherent in geotechnical work on projects, and it comes in several forms. A technical risk includes understanding the variability of the geotechnical profile beneath sites. Many of the standards included in FHWA manuals and this GPDM were put in place for the purpose of reducing the risks of unknown subsurface conditions beneath projects. Risk can be incurred with respect to cost when decisions are made regarding the scope of a geotechnical investigation. A greater investigation scope generally provides for a better understanding of the profile and means fewer unknowns are carried into construction, thereby reducing the risk of construction cost escalation. Risk is incurred with respect to serviceability when designs are advanced that do not fully address all possible modes of failure. Risk is incurred with respect to safety when geotechnical recommendations are incorporated into critical structures such as bridges, walls, and rock slopes. The Geotechnical Discipline's responsibility lies in identifying risks incurred through geotechnical issues, informing project team members and partners of these risks, and assisting in evaluating whether the risks are tolerable.

1.6 PROJECT DEVELOPMENT

The role of the Geotechnical Discipline is generally to provide geotechnical recommendations to a Project Manager or other designated members of an interdisciplinary (cross-functional), and possibly multi-agency project team. The Project Manager and other team members require geotechnical recommendations at multiple stages of project development and delivery, so the Geotechnical Discipline is an integral part of an interdisciplinary work plan. In general, there is a chronology to the logical execution of geotechnical tasks, as shown in the following outline. This section provides an overview of the tasks as a check list and the topics that are covered in more detail in subsequent sections.

<u>Initiate and Scope the Project</u>

- Participate in early project planning with the Project Manager and cross-functional team, defining the objectives and general scope of the project.

<u>Study Available Geotechnical Data</u>

- Assemble and review pertinent available geotechnical information prior to site scoping, including available previous geotechnical exploration data/reports, aerial photos, record drawings for the existing roadway and/or structures, new construction features, geological information, USDA soils data, etc.

<u>Perform Field Reconnaissance</u>

- Conduct reconnaissance-level site investigation to observe surface conditions including general terrain and access constraints, exposures of geologic formations or geohazards and apparent utility conflicts or other physical features in the area that may need to be addressed in the field exploration plan. This task generally does not include the subsurface exploration at this stage.

<u>Perform Preliminary Project Investigations</u>

- As necessary, conduct preliminary site investigations supporting line and grade planning, including observational assessment of roadway conditions, hazards, structures, and drainage, and limited sampling of material sources, soil/rock cuts. Prepare a punch list characterizing earthwork requirements, available material sources, geotechnical hazards, corrosive soil/rock/water conditions, drainage issues, candidate structure foundation types, and construction issues, all based on the preliminary work. Make recommendations for supplemental investigations.

<u>Perform Project Investigations</u>

- Conduct surface/subsurface investigations in support of the project plans, including soil/rock surface mapping, drilling and sampling programs, geophysical investigations, in-situ testing, and instrumentation deployment.
- Develop and implement a laboratory testing program supportive of project requirements.

<u>Compile and Summarize Data</u>

- Compile subsurface exploration logs, geophysical logs, materials data, soil surveys, groundwater/sub-excavation problem areas, field and laboratory test results, instrumentation monitoring data, and soil/rock profile data.

<u>Perform Geotechnical Analyses</u>

- Determine the scope of the analyses.
- Evaluate the accuracy and relevance of the available geotechnical data.
- Select values for design with an understanding of uncertainty and variability.
- Conduct the range of geotechnical analyses required to support the project, including assessment of construction options.
- Provide preliminary recommendations.

<u>Prepare Geotechnical Report</u>

- Review the ADOT report checklist listed in Section 6.3 of the manual to properly summarize relevant project investigation and design analyses information.
- Prepare a Geotechnical Report for the project, including a description of investigations, findings, analyses, and recommendations.

- Follow accepted QA/QC procedures for ensuring the quality of the analyses, recommendations, and final report.

Provide Design and Construction Support

- Attend project meetings concerning geotechnical issues, verifying that all geotechnical recommendations are being adequately incorporated into designs.
- Review PS&E packages.
- Assist Construction with monitoring and troubleshooting of geotechnical related construction issues and activities. A Post Design Services contract may be required to provide this service.

Field Investigation Preparation

- Gather project details from the PM to establish level of Scope
- Collect and review all available data that may provide pertinent site information
- Perform a reconnaissance-level site visit to become familiar with geologic/geotechnical setting, the terrain and possible field constraints to an investigation
- Prepare a preliminary investigative plan based on above
- ADOT Geotechnical Services to review plan

Field Investigation Execution

- Prepare a safety plan
- Prepare traffic control plan and encroachment permit
- Obtain utilities clearance prior to mobilization
- Mobilize equipment and conduct exploration based on plan
    - Supplement with geologic mapping/seismic surveys to fully characterize geologic profile and geotechnical properties as needed.
- Document all work and conditions on appropriate daily forms and logs
- Secure and protect all samples to preserve sample integrity prior to transport

Analysis

- Evaluate laboratory testing protocols needed for scope and send samples to the laboratory for testing
- Compile and summarize all data including logs, cross sections, images, notes, and laboratory test results
- Perform geotechnical analysis for project features defined in the scope and select design values

Reporting

- Review the ADOT report checklist listed in Section 6.3 of the manual to properly summarize relevant project investigation and design analyses information.
- Prepare a Geotechnical Report for the project, including a description of investigations, findings, analyses, and recommendations.

- Follow accepted QA/QC procedures for ensuring the quality of analyses, recommendations, and final report.

2 CHAPTER 2 – PLANNING

2.1 INTRODUCTION

A subsurface investigation generally will be required at the site of proposed roadway construction projects including those for widening and rehabilitation. Construction projects consisting of structural elements (e.g., bridge, walls) will require a subsurface exploration program to address foundation conditions. This Chapter presents guidelines to plan the scope of a geotechnical exploration, including a subsurface exploration and testing program. However, as the requirements and conditions vary with each project, engineering judgment is essential in tailoring the exploration to the specific project.

2.2 PROJECT REQUIREMENTS

The first step in developing a geotechnical investigation is a thorough review and understanding of the project details and requirements. It is important that geotechnical explorations be carefully planned and coordinated between those who will obtain the field data and the end-users of the information.

Depending on the stage of project development, the Geotechnical Engineer should have access to typical sections, plans and profile sheets, and cross sections with a template for the proposed roadway showing proposed cuts and fills. This project specific data aids the Geotechnical Engineer in planning the exploration to meet the project requirements. One goal of properly planning a geotechnical exploration is to optimize exploration costs and the number of site visits needed to obtain vital design information. Prior to performing any field work, the Geotechnical Engineer must be granted access to the site through the ADOT Right of Way Section and ADOT Environmental Planning Group and be prepared to address any environmental concerns or limitations associated with the project. Following the identification of proposed exploration areas, utility locations and clearances shall be obtained.

2.3 REVIEW OF EXISTING DATA

The first step in becoming familiar with site conditions and potential constraints should be the acquisition and review of existing data. ADOT maintains a comprehensive library of pertinent reference documents that may include: record drawings, aerial photographs, materials inventories, and related documents. The drawing shall include project specific plans and profile of the planned improvements. Geologic data, hydrologic data, seismicity data, fault maps, soil data, aerial photographs, topographic maps, and other information may be obtained from a variety of sources including but not limited to the following:

- Arizona Geological Survey (AZGS)
- U.S. Geological Survey (USGS)
- Natural Resource Conservation Service (NRCS)

- Arizona State Land Department (ASLD)
- Arizona Department of Water Resources (ADWR)
- Flood Control Districts
- Web-based Searches
- Earth fissure maps from AZGS
- Land subsidence map from ADWR
- Geotechnical reports for previous or nearby projects (contact ADOT Geotechnical Services)

2.4 SITE RECONNAISSANCE AND DEVELOPMENT OF EXPLORATION PLAN

2.4.1 Site Reconnaissance

The Geotechnical Engineer should conduct a site reconnaissance of the project site to gain an understanding of the geologic, topographic and geotechnical conditions at the site, and to evaluate site access and working conditions.

Prior to conducting the site reconnaissance, the geotechnical engineer should be familiar with the scope of the project and should have reviewed available data as described in Section 2.3. Project descriptions, plans and maps should be brought to and reviewed in the field, and detailed notes should be made of observations. Site conditions and items of interest should be photo-documented.

This method allows for the direct observation of aerial exposures of geologic units and structures and is a cost-effective approach for data collection to further anticipate what geologic formations may be encountered in future planned borings. This method includes characterizing the geomorphological terrain/features which can help induce the origin of the depositional setting at the site and type of materials to be expected. This method requires good observation skills and training in geologic processes. Observation of exposed walls of drainages may be very helpful in indicating materials forming the subsurface. It is accomplished without other geotechnical equipment. Observation of exposures and existing road cuts should be included in the reconnaissance.

2.4.2 Development of Exploration Plan

The field exploration methods required for field sampling and testing will depend upon the project design requirements, the subsurface conditions, and the availability and usability of existing data. Investigative field programs commonly include the following elements:

- Geologic mapping
- Geophysical surveys
- Test Borings
- Test Pits (trenches and hand sampling)
- Sampling (soil, rock, pavement cores)

- Pavement Condition Surveys
- Instrumentation and Piezometer installations

ADOT has established minimum requirements for the locations, spacing and depth of borings and test pits for specific project elements. The requirements are presented in Section 4. The requirements should be modified as necessary to adequately evaluate site-specific conditions. Once established, the exploration plan shall be reviewed by ADOT Geotechnical Services Engineer for concurrence prior to implementation.

It should be understood that initial investigative programs dealing with buried subsurface conditions are not always perfect and may be subject to change and modification, if field conditions warrant that change. Investigative programs may require a modification after the field work has been initiated due to variable subsurface conditions, the identification of unanticipated conditions, or site constraints. Field personnel should routinely communicate with the Geotechnical Engineer to inform them on progress and encountered geotechnical conditions. Field engineers/geologist have the responsibility to understand the objective of the investigation and contact the Geotechnical Engineer if they have questions or if problems are encountered.

3 CHAPTER 3 – FIELD EXPLORATION METHODS AND PROCEDURES

3.1 INTRODUCTION

The following sections provide an overview of the most common field exploration methods utilized by the Geotechnical Profession for transportation projects. Emphasis is placed on providing guidance for conducting comprehensive field exploration, establishing standard operating procedures for recording field data and collecting samples, and thoroughly documenting all field information. Special emphasis is placed on the classification and description of soil and rock, and the preparation of boring logs since this data is crucially important in obtaining high quality data needed for design.

Due to the variability and complexity of projects and subsurface conditions, engineering judgment and experience should be applied as specific applications of the guidelines for conducting a cost effective and practical geotechnical exploration. However, there are fundamental required data that should be obtained and basic steps that should be followed for any project. The collected field data and assessments are the basis for all subsequent engineering decisions and, as such, are important to the design and success of a project. The following are fundamental required data that should be obtained during a geotechnical exploration:

- Identification and delineation of existing soil and rock strata including predictability of the profile.
- Qualitative and quantitative information on the character and engineering properties of the soil and rock strata.
- Groundwater levels.

- Slope stability conditions, fissures, faults and other geologic hazards or constraints.
- Condition and performance of existing transportation structures.

The following references provide extensive information on how-to conduct geotechnical and subsurface exploration:

- FHWA Geotechnical Fundamentals for Transportation Projects (GFTP) manual (estimated release in Summer 2021) which is replacing the FHWA Soils and Foundation Reference Manual Volumes I and II (FHWA NHI 06-088 and 06-089)

The following reference may be applied until the release of the GFTP:

- Geotechnical Engineering Circular No. 5, Geotechnical Site Characterization (FHWA NHI-16-072)

Minimum qualifications for field personnel shall be a bachelor's degree from an accredited engineering or geology program.

3.2 SUBSURFACE EXPLORATION METHODS

Subsurface investigation methods most commonly include drilled borings, and/or excavated test pit and trenches. Drilling is the standard and preferred method for subsurface exploration and sampling. Use the appropriate exploration methods for the anticipated ground conditions to optimize surface and subsurface characterization and sample recovery for roadway and structure design.

3.2.1 Borehole Drilling and Sampling Programs

The objective is to develop a drilling program tailored to the anticipated subsurface conditions that can be used to obtain the required geological and engineering data necessary to evaluate foundation conditions. The Geotechnical Engineer is responsible for establishing the appropriate drilling techniques for the anticipated subsurface conditions; develop an effective and efficient drilling program that will accomplish the investigative objectives; and consider site constraints and safety and environmental aspects of the drilling program.

The following are the key issues when selecting drilling equipment/sampling techniques and performing drilling programs:

- Be familiar with the scope of the project and the drilling and sampling requirements.
- Review existing data to become familiar with site conditions.
- Maintain communication with the geotechnical engineer and provide updates with work progress, changed conditions and any problems.
- Engage the driller for information while drilling and to assure specifications are understood and followed at the beginning of the work to help achieve a high-quality field product.

- Be prepared and bring all necessary tools and equipment to the site to mitigate lost time.
- Complete all forms (daily reports, drill logs, sample tags, etc.) and review and sign driller's logs.
- Verify that all samples are properly obtained and handled.
- Be observant of local exposure to aid in defining the top of a bedrock surface, since this can be difficult within a borehole, especially where large boulders or highly weathered rocks are present.
- Do not hesitate to contact the Geotechnical Engineer if any doubts or problems are encountered.
- Drill casing may be required in some units to stabilize the walls or bottom of the boring to prevent sloughing or cave-ins and continue advancement of the borehole.
- Depth to water measurements should be obtained in all borings that encounter groundwater. Measurements should be recorded at the time of drilling and upon completion of the test hole and first thing each morning before disturbing the hole with drilling if the borehole is not finished and left open overnight.

3.2.2 **Geotechnical Equipment**

Standard practice is to use equipment that is most advantageous to collecting high-quality subsurface data for the project. This may include drilling and in-situ sampling, open wall observation of test pit excavations, or geophysical methods that require interpretive methods to characterize material properties.

3.2.2.1 **Test Borings**

Borings are the most common method of exploration. They can be advanced using several methods with the most common listed below:

- Hollow-Stem Auger Boring with sampling without withdrawing the casing
- Solid Flight Auger Boring with limited sampling capabilities
- Rock Coring with N- or H-sized steel casing, both conventional and wireline options
  - Where a fractured rock mass is anticipated in a future cut slope area, other downhole testing including optical televiewer imaging can be performed in the rock core boreholes for fracture orientation data
- Percussion Hammer, above ground pile driving type (Becker Method) or down-hole air percussion with eccentric bit (ODEX, TUBEX) types
- Sonic Drilling
- Single and/or dual walled Rotary Wash-type Boring

Consult with ADOT Geotechnical Services prior to selecting the proper method(s) of exploration.

3.2.2.2 **Test Pits**

Open excavations are another method for shallow investigations. The open excavation allows the advantage of direct observation of soils and soil structure in the walls or floor of the excavation. This method can supplement deeper borehole programs or be used where deeper penetration of the subsurface are not required. Open excavations include the following methods of exploration:

- Backhoe Excavated Test Pits and Trenches
- Trackhoe Excavated Test Pits and Trenches
- Dozer trenches
- Hand Excavated Test Pits

3.2.2.3 **Geophysical Methods**

Geophysical exploration methods can sometimes provide general subsurface profile information, such as the depth to bedrock, depth to groundwater, and the extent of granular/rock areas, peat deposits, or subsurface anomalies. Geophysical exploration methods including seismic refraction and/or electrical resistivity can provide a rapid and economical means of supplementing subsurface borings and test pits. These exploration techniques are most useful for extending the interpretation of subsurface conditions beyond what is determined from small diameter borings. A limitation of these techniques is that no samples are recovered. It must be emphasized that geophysical exploration methods might not be successful in all situations and should be carefully evaluated to determine whether geophysical methods add value and are appropriate for the specific project requirements and site conditions.

Consult with ADOT Geotechnical Services to discuss the appropriate type of geophysical test that may be applicable for a specific project.

3.3 SUBSURFACE SOIL SAMPLING AND COLLECTION

The following items are general guidelines and considerations when obtaining soil samples by drilling techniques.

- Undisturbed samples – generally obtained in cohesive soils and used to determine specific engineering properties (strength, density, permeability, consolidation, etc.).

  Undisturbed samples (or in this case, relatively undisturbed samples) are collected by penetrating a ring-lined barrel sampler into the subsurface soils. Continual use of the rings during field sampling and laboratory testing will cause deterioration and they may become deformed and pitted. Rings in such conditions are considered unacceptable for laboratory testing. The field representative must ensure that the rings are in acceptable condition and to discard any that are not acceptable, as described above. In addition, the ring-lined sampler shoe shall be in good condition, round and not deformed or dented.

- Disturbed samples – generally used to identify soil components and for general classification purposes (grain size, Atterberg limits, moisture/density, etc.).
- Bulk samples – generally obtained as disturbed drill cuttings from the upper portion of boring that can be used for R-value, moisture-density relationship (Proctor), and grain size analyses. All particle sizes should be sampled. If very coarse materials are present (cobbles and boulders) the maximum particle size shall be measured and the materials shall be estimated by weight percentage with other grain sizes (e.g., 10% cobbles, 45% gravel, 40% sand, 5% fines). Collections of bulk (auger-type cuttings) samples from deeper levels of the boreholes are more difficult to collect due to mixing of the soil column. If required, consider methods to reduce contamination and assure sample integrity.

  Bulk samples collected from sonic drilling methods are generally high quality samples from the sample interval. At a minimum, representative samples of the bulks should be retained and the entire sample interval shall be photographed.
- Sampler interval – relatively undisturbed and disturbed soil samples collected by ring-lined sampler or split-spoon sampler, respectively, are typically obtained at five foot intervals with the exception of the first five feet which should include a sample at roughly 2½ feet.
- Borehole termination – in general, a boring should not be ended in a soft or loose soil stratum with sample N-value <10 or in an unsuitable material (e.g., fill). N = number of blows of Standard Penetration Test (ASTM D1586). The number of equivalent blows with a ring-lined barrel sampler is roughly half of the SPT N-value. This value for ring-lined samplers is strictly for simplicity in the field. Engineering analysis of this value will vary based on published correlations for varying soil types.
- Sample identification – every sample attempt should be noted on the log, including sample type, interval, and blow counts. Individual samples are usually identified by the boring number followed by the depth interval. All soil samples and rock cores presented for testing to the ADOT Construction and Materials Group Central Laboratory must include sample ticket form 44-9346 R3/92 (or similar electronic reproduction) for each individual sample. The sample tags and logs shall accurately list the actual interval driven and not just reference the depth of the top of the sample interval.
- Sample preservation (disturbed grab samples) – disturbed samples should be placed in heavy duty double paper bags, cloth sacks, or heavy duty double plastic bags (to retain moisture content, if necessary). The sample tag should be as described above.
- Sample preservation (relatively undisturbed samples) – after retrieving the ring sample, place soil/ring group into plastic bag and insert into PVC tubes with tight rubber lid and tape to contain moisture. During transport, position and secure tubes vertically to prevent movement or shifting of the sample within the transport container. The samples should also not be subjected to freezing or excessive high temperatures.

- Sample storage – samples should be stored in designated locations (protected from rain, sun, and theft), and work orders listing each of the samples should be completed and provided to the geotechnical engineer along with the boring logs.
- Sample size – the minimum sample collection size shall be dictated by the laboratory tests to be performed on the sample. See below in this section for minimum sample sizes required per laboratory test.

The following items are general guidelines and considerations when obtaining soil samples by excavation techniques.

- Representative samples should be obtained from each major soil unit.
- Bulk samples may be obtained directly from shallow test pits or trenches by cutting a vertical, uniform channel along the entire thickness of a soil unit. Alternatively, the backhoe operator can be instructed to sample specific soil horizons by scraping the bucket along the pit wall.
- The sample should be placed in a bucket, cloth sack, or plastic bags (to maintain the moisture content of the sample). Care should be used to make sure that the sample is representative of the excavated materials, with the exception of collecting larger cobbles and boulders-sized materials. Samples that are collected from the excavated piles should be collected from several different portions of the pile to properly represent the materials.

3.3.1 Soil Sample Quantities

In order to perform laboratory tests according to the proper test procedure, a minimum amount of material is required. Listed below in Table 1 and Table 2 are the individual test methods with the recommended minimum amount of material that is required to perform the test.

Table 1 – Minimum Sample Sizes for Laboratory Testing

Test Method	Minimum Sample Size, grams (lbs.)	Material	Reference
R-Value	15,000 (33)	<#4	AASHTO T190
Proctor (Method A)	12,500 (28)	<#4	AZ 225c
Proctor (Method C)	13,000 (29)	<#4	AZ 226
Proctor (Method D)	25,000 (55)	<#4	AZ 226
pH and Resistivity	2,000 (5)	<#4	AZ 236c
Sulfates in soil	500 (1)	<#4	AZ 733a
Chlorides in soil	500 (1)	<#4	AZ 736a
Atterberg limits	500 (1)	<#4	AASHTO T89-90
Sieve Analysis	See Table 2 below	See Table 2 below	AZ 201c

Table 2 – Sieve Analysis Sample Sizes

Nominal Maximum Size of Particle	Minimum Weight of Sample, grams (lbs.)
3/8"	1,000 (2.2)
1/2"	2,000 (4.4)
3/4"	5,000 (11)
1"	10,000 (22)
1-1/2"	15,000 (33)
2"	20,000 (44)
2-1/2"	25,000 (55)
3"	30,000 (66)
3" slot	35,000 (77)

Note that the sieve analysis sample sizes listed in the table above may not be practical in cases where the only attainable sample may be from that of a sampler with limited material or volume retrieval. In such cases, lesser amounts of soil sample will be acceptable provided that such instances are mentioned in the Geotechnical Report.

3.4 BOREHOLE LOGGING

Detailed descriptions and classifications of soil and rock are an essential part of the geologic interpretation process and close inspection of the materials and soil structure is crucial for understanding the expected soil behavior to support design and construction. This section contains guidelines for preparing soil and rock logs.

The following references provide additional information on logging soil and rock samples:

- FHWA Geotechnical Fundamentals for Transportation Projects manual (estimated release in Summer 2021) which is replacing the FHWA Soils and Foundation Reference Manual Volumes I and II (FHWA NHI 06-088 and 06-089)

The following reference may be applied until the release of the GFTP:

- Geotechnical Engineering Circular No. 5, Geotechnical Site Characterization (FHWA NHI-16-072)

A lithologic log shall be made for every exploratory method including machine drilled boreholes, hand-auger holes, and test pits.

The field log is a record which shall contain all the information obtained from an exploratory hole and prepared on-site at the time of exploration. It is important to record all information to document activities required to penetrate the formations and a compile and detailed soils description of each layer encountered. All soil and rock samples are to be fully described immediately on recovery. The log of the test boring shall indicate the following information:

- Boring number or identifier
- TRACS number
- Boring location (station and offset, if appropriate)
- Surface elevation
- Boring orientation (if other than vertical)
- Name of logger and drill rig operator
- Type of drill rig
- Drilling methods
- Date and time started and completed
- Groundwater level with date measured
- Global Positioning System (GPS) location (hand-held device as a minimum)

Each sample should be fully described. Referencing a previous sample is not recommended since rarely are any two samples identical. However, don't repeat the description if the same unit extends further down the boring, just note the bottom contact of that layer. The depth of each stratum contacts shall be recorded with notes as to the presence of thin intermediate layers or lenses. It is important to log the entire length of the boring and not just the samples. Contact lines shall be drawn on the log at every change in materials and the contact should be based on samples, drill cuttings and drilling changes, based on rate of penetration changes and direct communication with the driller. The reason for terminating an exploration hole and a list/description of instrumentation installed should be written at the end (bottom) of each exploration log.

3.4.1 **Soil Logging**

On boring logs, the general description of soils is recommended as follows:

- Group Name based on main constituents
- Group Symbol (USCS Designation)
- Estimated percent of gravel, sand or fines (also cobbles if possible)
- Gradation of coarse grained particles
- Maximum particle size, and presence of cobbles and/or boulders based on drilling conditions since they cannot be directly collected in small diameter samplers

  Particle angularity for the coarse fraction
- Consistency/relative density

- Plasticity
- Relative moisture content
- Cementation, if present
- Reaction with HCl
- Color
- Origin (e.g., colluvium, fill)

Refer to ASTM D 2488 for further guidance in visual and tactile identifications and description procedures.

3.4.2 Rock Logging

On boring logs for rock the description shall include the following conditions:

- Formation or unit name (use formal name if available)
- Rock type or lithologic name
- Texture describing grain/particle size
- Hardness/strength
- Weathering
- Bedding
- Discontinuity spacing
- Discontinuity condition: clean, stained or in-filled and type of filling if filled
- Joint condition: degree of roughness
- Size and distribution of any voids
- Foliation or flow structure
- Structure (e.g., laminated, blocky)
- Color (Munsell soil or rock color chart is preferred)

The guidelines presented in International Society for Rock Mechanics (ISRM), Commission Standardization of Laboratory and Field Tests should be reviewed for additional information regarding logging procedures for core drilling.

3.5 TEST PIT AND TRENCH LOGGING

The objective is to provide a factual, accurate and concise record of important geological and physical characteristics of engineering significance from which subsequent conclusions regarding foundation conditions can be based. Responsibilities include providing accurate, consistent, and concise record of subsurface geologic conditions, providing quantitative and qualitative descriptions of geologic materials, and tailoring the log to meet the project needs.

3.5.1 General Test Pit Information and Practice:

- Test pits and trenches allow detailed examination of soil and rock conditions at a relatively low cost and are especially useful:
    - where significant variations occur over short distances (both vertically and horizontally)
    - large particles or materials prevent sampling using conventional methods
    - buried features such as fissures or faults may be examined and/or measured
- Test pits and trenches generally are excavated with backhoes or trackhoes. Depths are determined by exploration requirements, but typically limited to the reach of a standard backhoe (10 to 15 feet). If deeper test pits or trenches are required, the excavation may be performed by an excavator (trackhoe). The reach of typical excavators will normally extend to depths of approximately 20 to 30 feet.
- All test pit excavations shall be performed in accordance with Occupational Safety and Health Administration (OSHA) regulations.
- It is often useful to excavate test pits/trenches in an orientation that allows sunlight to illuminate one side of the pit wall. This also is helpful when photographing the pit wall. A small mirror reflecting the sun will provide a clearer and brighter view of the test pit walls and bottom.
- Test pits/trenches should be logged using a format similar to that for test borings and using similar visual classification and descriptive terms.
- A graphical log may be used to supplement the lithologic descriptions to highlight the nature of the units including contacts and structure where important to understand the deposits and possible evidence of geohazards.

3.6 SAMPLE PRESERVATION AND SHIPPING

Samples of soil and rock are obtained for classification and subsequent testing to determine their various engineering properties. Rock and soil samples represent essential physical information concerning the subject site. In general, these samples can be expensive to obtain. Samples must be preserved, stored, and shipped under conditions that minimize chances of disturbance or loss. Refer to Section 4.3 of the GPDM for more specific information regarding the sample preservation of disturbed soil samples and relatively undisturbed samples.

All soil samples and rock cores must be clearly, accurately, and permanently labeled to show all pertinent information which may be necessary in identifying the soil samples or rock cores, and in determining the character of the subsurface condition. The preserving, protecting and transporting of samples may be accomplished by any method that protects the sample from shock, detrimental temperature changes (such as freezing), and moisture loss. For further information, reference ASTM D 4220-95(2007), Standard Practices for Preserving and Transporting Soil Samples.

All soil samples and rock cores presented for testing to ADOT Construction and Materials Group Central Laboratory must include sample ticket form 44-9346 R3/92 (or similar electronic reproduction) for each individual sample.

Soil samples retained by the consultant shall be stored by the consultant until the geotechnical report is finalized or for longer periods at the discretion of the consultant and ADOT Geotechnical Services. Rock cores retained by the consultant shall be stored by the consultant until construction of the project is completed. Consult with ADOT Geotechnical Services prior to disposal of any rock cores.

3.7 INFILTRATION TEST METHODS

For project sites that are designed to contain stormwater storage facilities (e.g., retention basin, detention basin), infiltration tests should be performed in accordance with the requirements of the governing local municipality. Otherwise, the infiltration tests shall be performed in accordance with the Flood Control District of Maricopa County (FCDMC) Drainage Design Manual Volume II – Hydraulics Section 9.3.1. Procedures listed in the FCDMC manual include the double-ring infiltrometer test in accordance with ASTM D3385 and the EPA Falling Head Percolation Test Procedure from Design Manual – Onsite Wastewater Treatment and Disposal Systems (EPA 1980).

Occasionally, infiltration tests will be required at the location of stormwater storage facilities that have been previously constructed or are under construction. There are also situations where the infiltration test location cannot be accessed or tested by the methods mentioned above. In such cases, contact ADOT Geotechnical Services for further assistance prior to performing the infiltration tests.

3.8 PIEZOMETER INSTALLATION

Shallow groundwater can significantly affect the design, construction or performance of highway facilities. This includes but is not limited to, bridge crossings, bank protection, scour retrofit, and landslides. As part of the geotechnical exploration, piezometer installation is required where there is a reasonable likelihood that shallow groundwater may be encountered during construction. Piezometer installation must meet the requirements of Arizona Department of Water Resources (ADWR) for installation and abandonment. Groundwater readings shall be obtained at the time of drilling, after completion of the test hole, and 24 hours afterwards. Additional monitoring of groundwater levels shall be conducted on a seasonal or as-needed basis to evaluate the variability of water levels.

3.9 INSTRUMENTATION

Geotechnical instrumentation may be required depending on the scope of the project, the design elements, and the site conditions. Selecting and installing the proper instruments correctly are important. A discussion of installation procedures for selected instruments is provided in Appendix A of the AASHTO Manual on Subsurface Exploration, 1988. An in-depth discussion on the installation of Inclinometer Casings is provided in Section 4.1.5 of Chapter 11 of the TRB Special Report 247, "Landslides: Exploration and Mitigation". Such summaries are not intended to be a strict requirement, nor are they all inclusive of the variety of methods and procedures that may be used for the installation of instruments. The installation techniques may need to be customized to address specific subsurface conditions.

3.10 PHOTOGRAPHIC RECORD

Sites should be photographed to document the existing surface and surrounding condition of the project area. Photographing more details of the features of the site would better document the existing condition of the site. These photos should be included in the project files and some used in the geotechnical report.

Rock cores, and possibly drive samples, are usually the only physical sample evidence of the subsurface profile that remain available for a site. In order to maintain the integrity of this record, it is required to photograph the samples before portions are removed for testing purposes, or drying, or other disturbance occurs. Photographs assist to preserve the sampling record in the event that vandalism, negligence, or natural calamity causes loss or destruction of the physical sample. It also may be desirable to photograph specific sampling techniques and equipment for future reference. Care should be taken to optimize the size of the core within the photograph in order to show as much detail as possible. Color photographs are required for all rock cores.

3.11 INSPECTION OF EXISTING CUT SLOPES

Many roadway improvement projects include widening along existing roadways that have pre-existing cut slopes. Observation/inspection of the pre-existing cut slopes provides a cost-effective opportunity to characterize the geologic units exposed in the cuts and evaluate the performance of the slope. A documented inventory of the condition of the slope will aid the Geotechnical Engineer in design of expanded cuts and the information to be collected should include the following conditions:

- Slope orientation including strike and dip of the slope face
- Ditch width and shape
- Evidence of rockfall or other slope failures
- Description of the geologic units including features outlines in the borehole logging above
- Evidence of blasting/ripping
- Rating of the current performance

A photograph of the slope face can be used to prepare a graphic image of the slope that highlights important features.

3.12 STORM WATER POLLUTION PREVENTION PLAN (SWPPP)

Current rules and regulations that govern stormwater and non-stormwater discharge shall be followed on any size of ground disturbance. Current version of the ADOT Erosion and Pollution Control Manual and the ADOT Maintenance and Facilities BMP Manual can serve as guidelines for compliance.

4 CHAPTER 4 – GEOTECHNICAL INVESTIGATION REQUIREMENTS

4.1 GENERAL

An important step in geotechnical analysis and design is to have an adequate subsurface investigation program to characterize the geotechnical profile to mitigate risk. The prescribed approach for the various project features presented in this section is based on past experiences and lessons learned by the Geotechnical Profession with the goal of minimizing risk and avoiding potential impacts and changes during construction. However, this prescribed approach will not address all site conditions and the Geotechnical Engineer should use engineering judgment and their experience in the various terrains to develop the final investigative plan.

The Geotechnical Engineer should develop an overall program that addresses the geotechnical issues to the extent justified by the scope and significance of the project. The required investigative effort is also dependent on the type and complexity of the design. Adjustments in the exploration programs should be made as additional information becomes available. A phased exploration approach may be most beneficial for large projects and/or projects with difficult geotechnical problems. Unusual variations in geological stratigraphy may necessitate additional investigations. Actual geologic conditions should also be considered in developing the exploration depths (such as the actual depth to bedrock or hard strata). In some cases, the presence of unsuitable materials such as highly compressible soils may necessitate increases in number and/or depth of borings, possibly in a grid pattern to identify the lateral extent and depth of these deposits. Planning of exploration programs should consider the data required for the anticipated engineering analyses, time resources, environmental and risk constraints.

The Geotechnical Engineer shall submit their plan to ADOT Geotechnical Engineer for approval, prior to implementing geotechnical exploration activities. The guidelines for the minimum requirement of the exploration program are presented in the following subsections

4.2 EXPLORATION FOR STRUCTURES

4.2.1 Exploration Requirements

The guidelines shown in the *Minimum Number of Exploration Points and Depth of Exploration* in Table 3 below are to be used for determining the number and depths of borings to be made in each case. Exploration depths should be great enough to fully penetrate through soft or loose strata, into more competent material (e.g., stiff to hard cohesive soil, medium dense to dense cohesionless soil, or bedrock). All borings should extend through unsuitable strata such as collapsible soils, unconsolidated fill, peat, highly organic materials, soft fine-grained soils, and loose coarse-grained soils to reach hard or dense materials. In general, a boring should not be terminated in a soft or loose soil stratum ($N<10$) or in an unsuitable material. N = number of blows of Standard Penetration Test (ASTM D1586).

Table 3 – Minimum Number of Exploration Points and Depth of Exploration

Application	Minimum Number of Exploration Points and Location of Exploration Points	Minimum Depth of Exploration
Deep Foundations	For substructure unit (e.g., bridge piers, bents, or abutments) widths less than or equal to 100 feet, a minimum of one exploration point per substructure unit. For substructure unit widths greater than 100 feet, a minimum of two exploration points per substructure. Additional exploration points should be provided on abutments founded on bedrock or if erratic subsurface conditions are encountered, especially for the case of shafts socketed into bedrock. The test boring shall be placed within 10 feet of the foundation element (e.g., pier, pile). Any variance from this distance shall require the approval of ADOT Geotechnical Service. Non-redundant piers shall be drilled within the footprint of the foundation.	In soil, the depth of exploration should extend below the anticipated pile or shaft tip elevation a minimum of 20 feet, or a minimum of two times the maximum pile group dimension, whichever is deeper. All borings should extend through unsuitable strata such as unconsolidated fill, peat, highly organic materials, soft-grained fine soils, and loose coarse-grained soils to reach hard or dense materials. For piles bearing on rock, a minimum of 10 feet of rock core shall be obtained below tip elevation at each exploration point location to verify that the boring has not terminated on a boulder. For shafts supported on or extending into rock, a minimum of 10 feet of rock core, or a length of rock core equal to at least three times the shaft diameter, whichever is greater, shall be extended below the anticipated shaft tip elevation to determine the physical characteristics of rock within the zone of foundation influence. Note that for highly variable bedrock conditions, or in areas where very large boulders are likely, more than 10 feet of rock core may be required to verify that adequate bedrock is present.
Shallow Foundations	For substructure unit (e.g., piers, bents, or abutments) widths less than or equal to 100 feet, a minimum of one exploration point per substructure. For substructure unit widths greater than 100 feet, a minimum of two exploration points per substructure. Additional exploration points should be provided on abutments founded on bedrock, or if erratic subsurface conditions are encountered. The test boring shall be placed within 10 feet of the foundation element (e.g., spread footing, mat). Any variance from this distance shall require the approval of ADOT Geotechnical Service.	Depth of exploration should be: ▪ At least to a depth where stress increase due to estimated foundation load is less than ten percent of the existing effective overburden stress at that depth. ▪ If bedrock is encountered before the depth required by the criterion above is achieved, exploration depth should be great enough to penetrate a minimum of 10 feet into the bedrock, but rock exploration should be sufficient to characterize compressibility of infill material of near-horizontal to horizontal discontinuities. ▪ Great enough to fully penetrate unsuitable soils, e.g., peat, organic silt, or soft fine-grained soils, into competent materials of suitable bearing resistance, e.g., stiff to hard cohesive soil, or compact to dense cohesionless soil or bedrock.
Retaining Walls and Soil Nail Walls	A minimum of one exploration point for each retaining wall are required. For retaining walls more than 100 feet in length, exploration points spaced every 100 to 200 feet with locations alternating from in front of the wall to behind the wall. For anchored walls,	Investigate to a depth below bottom of wall at least to a depth where stress increase due to estimated foundation load is less than ten percent of the existing effective overburden stress at that depth and between one and two times the wall height. Exploration depth should be great enough to fully penetrate unsuitable soils, e.g., peat, organic silt, or soft fine-grained soils, into competent materials of suitable bearing resistance, e.g.,

Application	Minimum Number of Exploration Points and Location of Exploration Points	Minimum Depth of Exploration
	additional exploration points in the anchorage zone spaced at 100 to 200 feet will be required. The borings shall be placed within 10 feet of the foundation element. For soil-nail walls, add additional exploration points at a distance of 1 to 1½ times the height of the wall behind the wall spaced at 100 to 200 feet.	stiff to hard cohesive soil, or compact to dense cohesionless soil or bedrock.
Culverts	A minimum of one boring per major culvert. Perform additional borings for long culverts (greater than 100 feet in length) or in areas of erratic subsurface conditions. For culvert widenings, assess existing culvert condition prior to determining exploration need.	In stable materials, 15 feet below the culvert invert. Exploration depths should be great enough to fully penetrate through soft or loose strata, into competent material (e.g., stiff to hard cohesive soil, medium dense to dense cohesionless soil, or bedrock). All borings should extend through unsuitable strata such as collapsible soils, unconsolidated fill, peat, highly organic materials, soft fine-grained soils, and loose coarse-grained soils to reach hard or dense materials.
Existing Utility Towers	A minimum of one boring or test pit shall be completed within the roadway prism adjacent to the tower location.	The depth of the boring/test pit shall be consistent with roadway cut or embankment requirements in the GPDM. Refer to Section 5.5.3 of the GPDM for additional information on this topic.
Sound Walls	A minimum of two borings are required for sound walls with one test hole every 500 feet of wall length.	Extend borings to a minimum depth of 10 feet below the wall foundation.

4.2.2 Other Geotechnical Conditions and Structures

Consult with ADOT Geotechnical Services to determine a geotechnical exploration plan in areas with features such as: uncontrolled fills, fissures, geologic hazards, landslides, waste pits, aggregate pits, borrow pits, signals, signs, reclaimed surface mines, underground mines, lake, ponds, low-lying areas, karst formations, highly compressible soils, low strength soils, or structures or conditions not previously mentioned.

4.3 EXPLORATION FOR ROADWAYS

The geotechnical exploration for new roadway construction projects should include a thorough enough exploration and sampling of the subgrade to fully capture characteristics of all soil types and aid in the estimation of shrink or swell factors and compensation for ground compaction. Depending upon project needs, information is also required for the determination of appropriate cut and fill slope angles, recommendations for cut-widening, ditch geometry and exploration of near surface water conditions.

On reconstruction projects with minimal impact of new ground, the procedure may be simplified since sample locations will generally follow the existing centerline. The test hole excavation is also simplified since most holes will be fairly shallow.

The exploration requirements for construction projects consisting of roadway shoulder widening and multi-purpose paths shall be evaluated on a case by case basis and coordinated with ADOT Geotechnical Services.

Roadways for divided highways are generally considered to be two separate alignments. However, this consideration may vary depending upon the width of the median and other circumstances. Consult with ADOT Geotechnical Services regarding these situations.

4.3.1 **Sample Locations**

In general, the location of the test holes should be determined based on the geometry of the proposed centerline profile and cross sections. Where the terrain has no appreciable side slopes but has small cut-and-fill sections, test holes for sample collection for undivided roadways should be located along the centerline or staggered left and right of the centerline, depending on the locations of maximum cuts and fills and the underlying geology. Minimum depth of exploration is five feet below finished grade at 800-foot intervals.

Additional test holes may be required to define the limits of any undesirable materials or changes in soil stratification that could affect design and construction. The following subsections provide direction for sample frequency for the roadway components.

4.3.1.1 **Cut Slopes**

Test holes within the planned cut zone shall vary according to the site specific geometry and materials (rock or soils) within the cut area. At a minimum, the test holes should be placed within 25 feet of the opposite sides of the start and end of the cut areas. Depending on the length of the cut, it is recommended that test holes are advanced at a minimum of every 500 feet from the start and end of the cut. This distance may vary from project to project partially based on the expected variability of the geologic units and information needed to design a stable slope. The test holes shall extend to a minimum depth of five feet below finished grade. Consult with ADOT Geotechnical Services for further guidance and direction.

At locations of cuts deeper than 20 feet, additional test borings may be required in the transverse direction along the extent of the cut from the proposed toe to the crest of the slope to define the existing subsurface conditions for the stability analysis. In roadway widening projects where existing cut slopes exist, mapping of the existing cut slope can replace the need for the extra borings. For cut slopes deeper than 20 feet, perform geological mapping (e.g., slope inventory) along the length of the cut slope.

For drill rig explorations in cut areas, approximate in-place densities should be obtained from ring-lined samplers at every boring location, using ring-lined samplers, where feasible. Typical sampling patterns may include sampling on 2½-foot intervals (up to the first 10 feet) and alternating between SPT-samples and relatively undisturbed samples (such as ring-lined barrel samplers) as possible based on the subsurface materials encountered. Densities should be obtained from all holes if feasible. A bulk sample of auger cuttings shall be obtained and submitted for gradation, Atterberg limits and maximum density testing.

Occasionally, the opportunity to excavate test pits in the vicinity of test borings may arise and be necessary. If such is the case, obtain bulk samples at soil-type changes or at 2½-foot intervals to coordinate with the ring-lined samples.

Geophysical testing methods (i.e., seismic refraction survey) of cuts deeper than 20 feet are recommended to augment the test borings.

Consult with ADOT Geotechnical Services for further guidance and direction.

4.3.1.2 **Fill Slopes (Embankments)**

Test holes within the new fill zone shall vary according to the site specific geometry and materials (rock or soils) within the fill area. At a minimum, the test holes should be placed within 25 feet of the opposite sides of the start and end of the fill areas. Depending in the length of the fill, it is recommended that test holes are advanced at a minimum of every 500 feet from the start and end of the fill. This distance may vary from project to project. Test holes within the fill sections should extend to a depth of twice the height of the fill unless a hard stratum is encountered for a minimum of ten feet in depth. A hard stratum can be described as hard cohesive soils, very dense cohesionless soils, or competent bedrock.

However, the minimum guidelines may not be the same as the Depth of Significant Influence (DOSI) which is a function of the geometry of the embankment. For the same height of embankment, the DOSI increases as the base width of an embankment increases, and may vary from four to six times the height of the embankment. For further information on this topic, refer to the FHWA manual: NHI Course No. 132012, Soils and Foundations Reference Manual Vol. I (to be updated in Spring 2021 by the FHWA Geotechnical Fundamentals for Transportation Projects), and consult with ADOT Geotechnical Services.

Geophysical testing methods (i.e., seismic refraction survey) of new fills deeper than 20 feet are recommended to augment the test borings.

Consult with ADOT Geotechnical Services for further guidance and direction.

4.3.2 **R-Value**

After the test holes have been excavated and the standard samples have been taken, the minimum number of laboratory tested R-values (as per AASHTO T190) required for each major soil type is as follows:

- Projects with sections of roadway that include intersection improvements, turning bays, bridge approaches, etc., where the total length under construction is less than ½ mile shall be represented by a minimum of one R-value sample.
- On projects where the total length is between ½ mile and one mile, a minimum of two R-value samples shall be obtained.
- On projects greater than one mile, follow the sample requirements listed previously for the first one mile and then obtain a minimum of one R-value sample per additional ½ mile.

The above are minimum requirements. All representative material types shall be collected and tested, not only those which are considered to provide poor subgrade support. The engineer should analyze each project to determine actual sample locations and frequency. In some larger cut sections it may be necessary to obtain more than one sample if the change noted in the materials so warrants. The R-value test shall be accompanied by grain size analysis and Atterberg limits laboratory tests.

4.3.3 **Field Density Testing in Test Pits**

For the purpose of aiding in estimating earthwork factors, in-place field density testing is required within both cut and fill areas. Each estimated change in earthwork factor shall be tested for an in-place density in accordance with Arizona Test Method 235 (Density and Moisture Content of Soil and Soil-Aggregate Mixtures by the Nuclear Method) or Arizona Test Method 230a (Field Density by the Sand Cone Method). If the material within the limits of the estimated factor consists of more than one major soil type, additional tests should be performed to assure that all types are adequately represented.

Areas of materials that will be subject to swell, such as most rock, will not require in-place density testing.

A quality control test for the nuclear density gauge shall be performed by comparing the nuclear gauge readings to a sand cone test. A minimum of one sand cone test shall be performed for every ten nuclear density gauge tests of similar soil type.

For areas where field density testing is feasible, a recommended testing plan is outlined below:

- Cut Areas – For backhoe explorations, field density testing should be performed at test pit locations to be determined by ADOT Geotechnical Services. Each test pit may be tested at every change in material type to a maximum test pit depth of five feet below finished grade. For test pits deeper than five feet below finished grade, consult with ADOT Geotechnical Services for guidance.
- At each field density test interval, a sample shall be obtained and submitted for gradation, Atterberg limits, and Proctor (moisture/density) testing.
- All test pit excavations and inspection shall be performed in accordance with Occupational Safety and Health Administration (OSHA) regulations and the Site Health and Safety Plan.
- Fill Areas – Consult with ADOT Geotechnical Services for guidance.

4.3.4 **Other Geotechnical Exploration Considerations for Roadways**

For drill rig explorations in cut areas, approximate in-place densities should be obtained from ring-lined samplers at every boring location, using ring-lined samplers, where feasible. Typical sampling patterns may include sampling on 2½-foot intervals (up to the first 10 feet) and alternating between SPT-samples and relatively undisturbed samples (such as ring-lined barrel samplers) as possible based on the subsurface materials encountered. Densities should be obtained from all holes if feasible. A bulk sample of auger cuttings shall be obtained and submitted for gradation, Atterberg limits and maximum density testing.

If test pits are excavated in the vicinity of test borings bulk samples should be taken at soil-type changes or at 2½-foot intervals to coordinate with the ring-lined samples.

For drill rig explorations in existing fill areas, approximate in-place densities should be obtained at every boring location, using ring-lined samplers, where feasible. Typical sampling patterns may include sampling at the ground surface and at 2½-foot intervals (up to the first 10 feet) throughout the depth of possible removal due to compressible and/or collapsible soils. A bulk sample of auger cuttings shall be obtained and submitted for gradation, Atterberg limits and maximum density testing.

Consult with ADOT Geotechnical Services for further guidance and direction.

4.4 EXPLORATION FOR WIDENING OF EXISTING STRUCTURES

Projects involving the widening of existing structures on major highways are now common for urban areas. Generally, these structures were designed utilizing geotechnical exploration information provided during the original design phase.

Information from the original geotechnical exploration to be considered for expansion projects normally includes the locations of the original borings and the method and depths of drilling. Interpretation of this information may vary due to the inherent variety of conditions and circumstances for each project.

At times, the original geotechnical information is deemed insufficient for designing the structural element for the widening project. However, existing information from previous projects may be considered for design in widening projects provided the following conditions are met:

- Location of the original boring shall be within 10 feet of the new foundation footprint.
- Depth of the original boring shall extend to the depths stated in the foundation exploration guidelines found in Section 4.2.1 of this manual. Otherwise, use for information only.
- A hammer efficiency of 50% shall be used if the hammer efficiency from the original exploration is not provided.

Site plans depicting the original test boring locations may be vague or inaccurate. These locations will have to be further evaluated prior to determining if they are to be considered. Test boring locations with documented stationing, offsets, and/or GPS coordinates will also require further evaluation.

Other considerations from the original geotechnical exploration shall include drill rig type (e.g., CME-75), drilling method (e.g., hollow-stem auger, percussion hammer), and frequency of samples.

The geotechnical exploration for the widening shall meet the following guidelines:

- When a foundation element is widened on both sides of an existing structure, two borings will be required with each boring placed at opposite ends of the structure unless the criteria noted previously regarding the original test borings are met. If the latter is the case, when a foundation element is widened on both sides of an existing structure, a minimum of one new boring will be required regardless if the original test borings were located on both sides.
- When a foundation element is widened on one side of an existing structure, one new boring will be required.
- Reference the deep foundation exploration guidelines found in Section 4.2.1 of this manual to determine the minimum drilling depths. Each new foundation element shall be considered independent from any other new foundation element.
- New borings shall be drilled within 10 feet of the planned widened element to the extent practical. Variance to this distance may include buried or overhead utilities, and existing foundation conflicts such as battered piles or existing slopes.

All new foundations and structures will follow the same exploration requirements as directed in the previous sections of the manual.

Consultant shall contact ADOT Geotechnical Services for further guidance, direction, and approval on all widening projects.

4.5 EXPLORATION FOR MULTI-USE PATHS

Due to the minimal pavement thickness design that is required for light use pavement areas, geotechnical explorations are limited to investigating the upper five feet below finished grade at intervals spaced every 800 feet or otherwise directed by ADOT Geotechnical Services.

4.6 EXPLORATION WITHIN EXISTING PAVED AREAS

On occasion, geotechnical explorations may be necessary in existing paved areas consisting of asphaltic concrete (AC) and/or Portland cement concrete pavement (PCCP) overlaying aggregate base course (ABC) or similar sub-pavement materials. These types of explorations are generally performed for the purpose of investigating the subsurface materials for forensic studies, where thickness of the existing pavement is of interest or instances where test pits cannot be advanced outside of paved areas.

Typically, these types of explorations are performed with a drill rig with the borings advanced by hollow stem augers or pavement core machine.

The following items are considered best practices when performing geotechnical explorations in paved areas:

- The pavement in all borings areas shall first be cored to a width of 12 inches to minimize any uplift of the surrounding pavement during auger advancement and retrieval. The cored pavement section is to be measured for thickness with an assessment of the condition (if possible).
- Once the core is retrieved, advance the boring to the bottom depth of the base course (BC) material (or similar sub-pavement material) until reaching the subgrade soils. Measure the depth of the BC and note any characteristics of the material ("dirty" base course, cinders, etc.). It is important that all materials are removed from the cored section of the test hole to prevent the contamination of samples.
- Once the subsurface soils are encountered, with the test hole cleaned and the BC depth determined, sample the top of the subsurface soil layer with a ring-lined barrel sampler a total of 18 inches if possible. Record the blow counts in 6-inch intervals. Retain the bottom six rings for moisture/density and/or in-situ swell or consolidation testing. The remaining material (excluding any slough) from the upper 12 inches of the sample may be collected and used for gradation and Atterberg limits. Note that this direction is based upon the use of an extended length sampler (18 inches) which may not be readily available. If such is the case, reduce the lengths mentioned previously by 6 inches.
- Advance boring to next desired depth and repeat. Cuttings from auger spoils shall not be collected for laboratory testing as they are likely contaminated with BC material and or not representative of the subsurface soil conditions.

4.7 EXPLORATION NEAR UTILITY POWER POLES

In locations where the roadway alignment requires a cut slope within 75 feet of utility power poles, the following items shall be performed as minimum requirements. In general, a minimum set back distance of 75 feet (measured from the closest edge of the tower foundation to the slope crest or point where the cut slope "breaks") shall be specified. If conditions are such that this 75-foot distance is impractical to obtain, a site-specific design shall be developed. Input parameters for the minimum 1.5 safety factor determination and the analysis/design shall be developed.

The geotechnical field investigation shall be performed as specified previously in this GPDM. Upon completion of the field investigation, the Geotechnical Engineer shall consider necessary testing of samples required to perform the site-specific analysis/design for the slope adjacent to the tower location. The results and recommendation will be included in the project geotechnical report or a separate report shall be prepared; any required construction details and/or specifications will be included in the project plans and/or special provisions.

If geologic or other conditions exist such that 75 feet is not considered a sufficient set back distance, an analysis, design and report to determine the recommended distance shall be performed. Necessary construction details and specifications shall be included in the project plans and/or special provisions.

4.8 EXPLORATION FOR SCOUR RETROFIT AND BRIDGE REHABILITATION PROJECTS

Subsurface soil and/or rock parameters may be evaluated as necessary for these types of projects. Seismic refractions survey is the preferred and most effective method for determining the material type and characteristics without causing ground disturbance by drill rigs and backhoes. The approach shall be discussed and approved by ADOT Geotechnical Services.

4.9 EXPLORATION FOR LANDSLIDES

Due to the complexities and varying nature of landslides, the exploration approach shall be discussed with and approved by ADOT Geotechnical Services.

5 CHAPTER 5 – ANALYSIS AND DESIGN

5.1 INTRODUCTION

The following chapter provides guidelines pertaining to the analysis required for the design on ADOT projects.

5.2 EARTHWORK

The Geotechnical Engineer is responsible for reporting earthwork parameters including the shrink/swell factors for the excavated materials, the ground compaction factors, the estimated volume of water used for compaction of base and subgrade materials, and corrosion potential of in-situ materials.

5.2.1 Excavation Factors (Shrink/Swell)

This is an estimate of how much the material will change in volume when excavated and then compacted in a new embankment fill. This is typically reported to the nearest 5% increment (for example: 10% swell, even, 5% shrink). The reported value should represent an average for the entire volume of the prism of material to be excavated for a particular segment of the project area or the entire project area if the materials are similar.

Earthwork factors are determined by utilizing relative compaction comparisons based on laboratory test data, field density data (using rock correction factors), geophysical data, boring data or a statement of experience with similar materials. This type of analysis often results in considerable scatter in the calculated factors, but it can be a useful tool to formulate final earthwork factor design recommendations. In rocky areas where field density testing is not practical, other methods should be used.

Earthwork factors are dependent on soil/rock properties and characteristics including fracture patterns, hardness and degree of weathering in rock that affects the way the material breaks down into a soil like product. It is also dependent upon contractor methods of handling the materials, wind losses and compaction achieved during construction. The intent of an earthwork factor estimate by the Geotechnical Engineer is to simply provide a specific value (rounded to the nearest 5 percent) to facilitate the roadway earthwork estimate for design.

5.2.2 **Ground Compaction Factors**

The ground compaction factor is an estimate of ground height loss (including the losses incurred during clearing and grubbing) that will result from compaction of the surface to 95% relative compaction (based on Arizona Test Method 235 or 230a), which is typically done prior to construction of the new roadway embankment. The ground compaction factor is typically reported in increments to the nearest 0.10 foot, however, increments of 0.05 foot are acceptable.

Listed below are guidelines for recommended ground compaction factor values for various conditions. These values are not empirically determined, but are based on experience and judgment from previous ADOT construction projects.

- 0.00 foot – Negligible ground disturbance potential. Locations with hard/very dense surface soils with no fill placement or existing vegetation.
- 0.10 foot – Slight ground disturbance potential. Locations with sparse vegetation and/or minimal fill placement (less than 10 feet in depth).
- 0.20 foot – Moderate ground disturbance potential. Locations with moderate vegetation and/or moderate fill placement (roughly 10 to 25 feet in depth).
- 0.30 foot – Significant ground disturbance potential. Locations with heavy vegetation and/or significant fill placement (roughly 25 feet in depth and above).

5.2.3 **Water for Compaction**

The water for compaction is an approximation of the amount of water in gallons that is required per cubic yard of material for compaction of base and also subgrade materials. This estimate is based on the difference between in-situ and optimum compaction moisture content and includes a conservative overrun for losses due to seepage, evaporation, inadequate mixing, spillage, etc. The intent is to allow the contractor to acquire a sufficient quantity of compaction water for the given project.

5.2.4 **Corrosion Potential**

Chemical tests are performed to determine the corrosion classification of soil and water. This information is necessary to determine corrosion protection requirements for buried structures such as reinforced concrete box culverts, CMPs, piles, footings, etc. The tests are performed to determine the pH, minimum resistivity, sulfate content, and chloride content. In general, metal structures such as a CMP will require laboratory tests for pH and minimum resistivity, and concrete structures such as concrete box culverts will require laboratory tests for sulfate and chloride in soils. ADOT Construction and Materials Group Central Laboratory shall perform the sulfate in soils and chloride in soils tests, unless otherwise directed by ADOT Geotechnical Services.

5.3 ROADWAY PAVEMENT SUBGRADE SUPPORT

For projects requiring design recommendations for subgrade support, the Geotechnical Engineer is responsible for presenting the following information as part of the report: R-Value results (tested and correlated); recommended design R-value; control R-value; subgrade improvement techniques with discussion on geogrid base reinforcement and separation geotextile fabric placement; and/or subgrade improvements by over-excavation and replacement.

The recommended design and control R-value should be based on the method described in the updated ADOT Pavement Design Manual.

The correlated R-Value chart is available in the updated ADOT Pavement Design Manual issued September 2017, or most recent update.

5.4 STRUCTURE FOUNDATIONS

For all federally funded projects, the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications (Sixth Edition, 2012) is mandatory. In general, the LRFD approach as prescribed in the AASHTO LRFD Bridge Design Specifications shall be used, unless a LRFD design methodology is not available for the specific foundation type being considered, or unless modified or superseded by ADOT Geotechnical Design Policies that are listed in Sections 5.5 of the GPDM. Otherwise, for any other structural or non-structural design application, the Engineer is expected to prepare the Geotechnical Report consistent with acceptable practice and professional standards of that of a State of Arizona licensed Professional Engineer or Registered Geologist.

The following references provide additional guidance for structural design from FHWA and AASHTO.

- AASHTO Guide Specification for Service Life Design of Highway Bridges, 1st Edition
- Georisk: Assessment and Management of Risk Engineered Systems for Geohazards – Uncertainty in Differential Settlements of Bridge Foundations and Retaining Walls
- Georisk: Assessment and Management of Risk Engineered Systems for Geohazards – Calibration of Foundation Movements for AASHTO LRFD Bridge Specifications Implementation Report - Expanded Database for Service Limit State Calibration of Immediate Settlement of Bridge Foundations on Soil, (FHWA-HIF-18-008)
- Implementation Report - Expanded Database for Service Limit State Calibration of Immediate Settlement of Bridge Foundations on Soil, (FHWA-HIF-18-008)
- Reliability Evaluation of Concrete Cover for Buried Structures from Chloride-Induced Corrosion Perspective

- Compendium of Service Limit State Development for Geotechnical Elements Designed by AASHTO LRFD (TRB Centennial Paper 1 – expected release in Spring 2021)
- Structural Implications Related to Foundation Movements in AASHTO LRFD (TRB Centennial Paper 2 – expected release in Spring 2021)

5.5 ADOT GEOTECHNICAL DESIGN GUIDELINES

The following subsections below present design guidelines specific to ADOT projects. Consult with ADOT Geotechnical Services engineer to discuss the design implementation of these guidelines.

5.5.1 Supplemental ADOT Design Guidelines for Spread Footings

ADOT has developed supplemental design guidelines for spread footings which modify the AASHTO (2010) LRFD Bridge Design Specifications. ADOT Materials Group maintains copies of these guidelines. Listed below are three ADOT Geotechnical Design Policies for spread footings.

- Geotechnical Design Policy SF-1 (December 2010)
  Development of Factored Bearing Resistance Chart by a Geotechnical Engineer for Use by a Bridge Engineer to Size Spread Footings on Soils based on LRFD Methodology

- Geotechnical Design Policy SF-2 (December 2010)
  Limiting Eccentricity Criteria for Spread Footings based on LRFD Methodology

- Geotechnical Design Policy SF-3 (December 2010)
  Resistance Factors for the Estimation of Factored Sliding and Bearing Resistance for Spread Footings of Gravity and Semi-gravity Walls based on LRFD Methodology

5.5.2 Supplemental ADOT Design Guidelines for Drilled Shafts

ADOT has developed supplemental design guidelines for drilled shafts which modify the AASHTO (2010) LRFD Bridge Design Specifications. ADOT Materials Group maintains copies of these guidelines. Listed below are three ADOT Geotechnical Design Policies for drilled shafts.

- Geotechnical Design Policy DS-1 (December 2010)
  Development of Drilled Shaft Axial Resistance Charts for Use by Bridge Engineers based on Load and Resistance Factor Design (LRFD)

- Geotechnical Design Policy DS-2 (December 2010)
  Design of Drilled Shafts in Gravel and Gravelly Soils Exhibiting Drained Behavior

- Geotechnical Design Policy DS-3 (December 2010)
  Analysis of Drilled Shafts Subjected to Lateral Loads based on LRFD Methodology

6 CHAPTER 6 – GEOTECHNICAL REPORT GUIDELINES

6.1 INTRODUCTION

This chapter describes the format and general outline for presentation of geotechnical data.

A Geotechnical Report is required on all proposed roadway and structure projects. Upon completion of the geotechnical investigation and analysis (previous chapters), the information and findings must be compiled in a standard report format. The study and report shall be made by an Arizona Professional Engineer who shall seal each document per the requirements of the Arizona State Board of Technical Registration. A written report shall contain information, analysis and interpretation of the subsurface conditions based upon all available sources of information and data. Data may come from new or previous explorations, laboratory testing, nearby construction experience, performance of relevant existing pavement or structures, etc.

The report serves as the permanent record of geotechnical data known to be pertinent to the project and is referred to throughout the design, construction, and service life of the project. The intent of the Geotechnical Report is to present the data collected in a clear manner, to draw conclusions from the data, and to make recommendations for the geotechnical aspects of the project. The primary users of the report include but are not limited to; roadway designers, bridge engineers, pavement designers, construction personnel including Quality Compliance individuals, and contractors.

The geotechnical information and types of recommendations to be provided in geotechnical reports are defined by the intended phase of the projects and may include conceptual, preliminary and final reports as outlined in the following sections.

6.2 CONCEPTUAL, PRELIMINARY LEVEL GEOTECHNICAL REPORTS

Conceptual level geotechnical reports (e.g., design concept report, desktop study) are commonly limited to an office review of existing geotechnical data for the site, and generally consist of a feasibility assessment and identification of geologic hazards. Geotechnical design for conceptual level reports is typically based on engineering judgment and experience at the site or similar sites.

For preliminary level design report preparation, a geological reconnaissance of the project site is usually conducted, as well as some detailed geotechnical analysis to characterize key elements of the design, adequate to assess potential alternatives and estimate preliminary costs. A limited subsurface exploration program may also be warranted under some circumstances.

Conceptual or preliminary level reports should contain a general description of the project and summaries of the following elements (where applicable): regional and site geology; field exploration; laboratory testing; subsurface conditions; geological hazards; geotechnical recommendations; and any appendices including soil profiles, boring logs, laboratory test results, figures, photographs or any other relevant information.

6.3 INITIAL GEOTECHNICAL REPORT

Initial geotechnical reports are only developed in circumstances where a project is developed in phases and requires initial geotechnical recommendations commonly of in-progress work. The information from the initial geotechnical reports generally will be incorporated into the final geotechnical report.

6.4 FINAL GEOTECHNICAL REPORT

Final geotechnical reports are developed based on an office review of existing geotechnical data for the site, a detailed geologic review of the site, and a complete subsurface exploration program meeting AASHTO and FHWA standards, and as augmented in the GPDM. Final geotechnical reports should contain, as a minimum, the following elements as they pertain to the specific project:

- A general description of the project
- Project site surface conditions and current use
- Regional and site geology
- Regional and site seismicity
- A summary of the site data available from project or site records
- A summary of the field exploration conducted
- A summary of the laboratory testing conducted
- Subsurface (soil, rock, groundwater) conditions
- Summary of geological hazards identified
- Analysis of cut and fill slopes
- Earthwork factors
- Rock slopes designs
- Stabilization treatments of unstable slopes
- Foundation design recommendations for bridges, hydraulic and other structures
- Foundation design recommendations for retaining walls and reinforced slopes
- Measured infiltration rates retention/detention facilities
- Recommendations for trench shoring design
- Pavement subgrade support
- Subgrade support for other project elements (e.g., fills, culverts)
- Long-term or construction monitoring needs
- Construction considerations
- Appendices with figures, laboratory test results, analysis and field data including borehole logs

6.4.1 Final Geotechnical Report Organization

The Geotechnical Report is to contain factual data, interpretations, engineering studies and analyses, and recommendations for design and construction. It is recommended that the report should be formatted to present information using a standardized outline, so that users are able to locate information readily and consistently. The format and contents of the Geotechnical Report depend on the type of project. In general, the recommended outline of the Geotechnical Report should be organized into chapters as follows:

- Title Page
- Table of Contents
- Introduction (some more complex projects may warrant an Executive Summary)
- Project Description
- Investigation performed, including description of each tasks completed for the project from planning to execution of the investigation
- Geologic Setting
- Site Conditions
    - Site Geology
    - Geotechnical Profile
    - Seismicity
- Analyses and Recommendations
- References
- Figures
    - Site plans
    - Cross Sections
    - Profiles
- Appendix A – Borings (Exploration) Logs
    - Key to symbols and terms
    - Boring Logs in graphical form
    - Previous boring logs including as-built logs from historic projects, if available
- Appendix B – Laboratory Test Results
- Appendix C – Design Charts
- Additional appendices as necessary

6.4.1.1 **Boring (Exploration) Logs**

Exploration logs shall be prepared by using software capable of storing, manipulating, and presenting geotechnical data in one-dimensional profiles. A two-dimensional exploration log may also be presented in a fence-type profile. Exploration logs are to be presented in Appendix A of the report.

Table 4 below lists the information required for the exploration logs and is divided into categories for either soil or rock exploration logs:

Table 4 – Exploration Log List

SOIL EXPLORATION LOG	**ROCK EXPLORATION LOG**
The items listed below are generally presented in tabular format within the log headers or footers	
Start and end dates	Start and end dates
Boring number or identifier	Boring number or identifier
Structural member identifier (e.g., Abutment 1, Pier 3)	Structural member identifier (e.g., Abutment 1, Pier 3)
Project name	Project name
Location	Location
ADOT TRACS number	ADOT TRACS number
Consultant project number	Consultant project number
Boring location (station and offset)	Boring location (station and offset)
GPS coordinate (NAD 1983)	GPS coordinate (NAD 1983)
State Plane Coordinate (if available)	State Plane Coordinate (if available)
Surface elevation of exploration hole/test pit	Surface elevation of exploration hole/test pit
Drilling subcontractor	Drilling subcontractor
Drill rig type	Drill rig type
Field engineer	Field engineer
Time started and completed	Time started and completed
Groundwater elevation with dates and time measured	Groundwater elevation with dates and time measured
Hammer drop system	
Hammer Calibration Energy Transfer Ratio	
The items listed below are generally presented in columnar format on the logs (or described within the column)	
Incremental elevation	Incremental elevation
Depth below surface at incremental elevations	Depth below surface at incremental elevations
Sample type	Sample type
Sample number or ID	Sample number or ID
Graphic symbol	Graphic symbol
Material description (see below)	Material description (see below)
Bottom of hole depth (indicate if refusal)	Bottom of hole depth (indicate if refusal)
Sample depth	Coring method (barrel type)
Blow counts (SPT or ring-sampler values)	Core recovery (%)
Driven sample length (in.)	Drilling fluid recovery (%)
Recovery of sampled material (in.)	RQD
Material description (see below)	Discontinuity spacing and orientation
Laboratory tests performed	Weathering

SOIL EXPLORATION LOG	ROCK EXPLORATION LOG
Dry density and moisture content	Rock Strength Index (rock hardness)
PI and % fines (both optional)	Joint condition and roughness
Blank	Core depth range
Blank	Penetration Rate

Material description for soil and rock shall include items listed in Chapter 3.

6.4.1.2 **Laboratory Test Results**

The results of the individual laboratory tests are to be presented in Appendix B of the report in the following order:

- Summary of Laboratory Test Results (see below for details)
- Grain Size Distribution presented graphically with plotted grain size vs. percent passing by weight curve (include up to five separate test results per graph)
- Mechanical Sieve Analysis (comprehensive sieve data sheet)
- Atterberg Limits Results
- Direct Shear
- Proctor
- Consolidation (one-dimensional collapse/compression test), and/or,
  Consolidation (time-rate consolidation)
- R-Value
- Unconfined Compressive Strength
- Corrosivity Tests (pH, Minimum Resistivity, Soluble Sulfates and Chlorides)
- All other laboratory test results

A summary of laboratory test results that include the data listed below is to be presented in tabular format.

- Test hole
- Sample number
- Sample type
- Depth
- Grain size distribution
- Atterberg limits (LL and PI)
- In-situ dry density (ring sample)
- In-situ moisture content (ring sample)
- USCS Classification
- R-Value (correlated)
- R-Value (tested)
- Proctor – maximum dry density (pcf)

- Proctor – optimum moisture (%)
- In-Situ – Dry density (pcf)
- In-Situ – Moisture content (%)
- Corrosivity test results (pH and Resistivity)
- Chemistry tests results (sulfate and chloride content, in ppm)
- Optional items
    - Station and offset
    - Roadway direction (e.g., 60-WB)
    - Mid-point elevation of sample
    - Liquidity Index with Atterberg limits
    - Any other data that are relevant to the project
    - AASHTO 1995 Classification

6.5 FOUNDATION DATA SHEET

Foundation data sheets shall consist of a site map showing the location of the borings relative to the structure as well as the boring logs. Appropriate notes as well as a key to the symbols and terms shall be included. The Geotechnical Engineer must provide detailed and accurate information on the boring logs and in the Geotechnical Report regarding the drilling process and description of encountered soils during the subsurface investigation. As part of the Foundation Data Sheet set, details of the soil and drilling conditions shall be summarized within a general notes section. All foundation data sheets shall be sealed by a registered engineer, for incorporation into the project plans.

6.6 GEOTECHNICAL REPORT DISTRIBUTION

All final reports (including supplements and memorandums) and other elements (upon request) must be submitted to the ADOT Bridge Group - Geotechnical Services. Generally, an electronic version of the report is sufficient, although projects that include geological maps or other large scale exhibits may require a hard copy submittal.

7 CHAPTER 7 – REFERENCES

7.1 REFERENCES

- AASHTO, 2012: *AASHTO LRFD Bridge Design Specifications, 6th Edition*, American Association of State Highway and Transportation Officials, Washington, D.C.
- AASHTO, 2020: *AASHTO Guide Specification for Service Life Design of Highway Bridges*, *1st Edition*, American Association of State Highway and Transportation Officials, Washington, D.C
- FHWA 2016, Geotechnical Engineering Circular No. 5, Geotechnical Site Characterization, FHWA NHI-16-072
- FHWA 2007, USDOT, Federal Lands Highways – Project Development and Design Manual, Chapter 6 – Geotechnical.

- Samtani N.C., and Kulicki, J.M., 2020: *Uncertainty in Differential Settlements of Bridge Foundations and Retaining Walls, Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards*, DOI: 10.1080/17499518.2020.1711526
- Samtani N.C., and Kulicki, J.M., 2018: *Calibration of Foundation Movements for AASHTO LRFD Bridge Design Specifications, Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards*, DOI: 10.1080/17499518.2018.1554818.
- Samtani N.C., and Allen T.M., 2018: *Implementation Report – Expanded Database for Service Limit State Calibration of Immediate Settlement of Bridge Foundations on Soil*, Publication No. FHWA-HIF-18-008
- Samtani N.C., and Kulicki, J.M., 2020: *Reliability Evaluation of Concrete Cover for Buried Structures from Chloride-Induced Corrosion Perspective*, ASCE 04020049

7.2 **REFERENCES PENDING RELEASE**

- Compendium of Service Limit State Development for Geotechnical Elements Designed by AASHTO LRFD (TRB Centennial Paper 1 – estimated release in Spring 2021)
- FHWA Geotechnical Fundamentals for Transportation Projects manual (estimated release in Summer 2021)
- Structural Implications Related to Foundation Movements in AASHTO LRFD (TRB Centennial Paper 2 – estimated release in Spring 2021)